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Eilcart, A. Solid Formulae, Models for use in teaching Organic Chemistry. 1/- Dec/91

G. S. Johnson Esq

With the author's kind regards.

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SOLID FORMULÆ; MODELS FOR USE IN TEACHING ORGANIC CHEMISTRY.

BY ARNOLD EILOART.

In lecturing on stereochemistry I have found models similar to those here described very helpful, and believe that they will prove useful also in general lectures on organic chemistry, elementary as well as advanced. These models do not pretend to represent any new conception as to the space-relations of atoms, but merely conveniently to represent established conceptions; further, they are not intended to supersede existing models, but to supplement them, for if only one sort of model be used there is danger that what is accessory may be considered essential; but when the same idea is represented by a variety of models it is seen that the essential is common to all, while variation of the accessories makes plain their non-essential nature.

That which is common to all models representing the space-relations of radicals attached to a carbon-atom is the prominence of four equidistant points; for although different radicals probably place themselves at different distances from the central carbon, they are for convenience represented as equidistant from it and from one another. Thus Van't Hoff used a regular tetrahedron, of which the centre and the four corners represented the relative positions of a carbon-atom and the radicals attached to it, a carbon-atom attached to unlike radicals being represented by a tetrahedron with the corners of different colors. The essence of the present device is the use of letters instead of colors at the corners

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of the tetrahedra. As by means of caps fitting over the tetrahedron corners Van't Hoff could change their colors, so can the letter-symbols be changed by exchanging one cap for another. In addition, means are provided for supporting the tetrahedra so that the caps may be readily changed, for holding the cap on the corner it covers, for connecting the tetrahedra by one or by two corners, and for easy transition from the single to the double connection as well as *vice versa.*

The figures (see Plates) show the arrangements.[1] It will be seen that when the tetrahedra are joined at one corner only the hinged connecting rod remains straight, because it sinks just so far into the lower tetrahedron that the hinge is covered. To convert the corner-connection (single-bond) into the edge-connection (double-bond), a pin is placed in the middle of that edge of the lower tetrahedron which is to be joined to the upper one, the latter is slightly raised, the little finger of the hand which raises it is used to lift the hinged rod till the hinge is free, and now any free corner of the upper may be made to touch the proper corner of the lower tetrahedron, and the pin will make the connection secure. This pin fits into the lower tetrahedron so tightly that it remains there when the edges are separated for restoration of the single-bond. These manipulations take a few seconds only. To test the durability of the arrangement by which the caps are held in place, some of them have been put on and off many times, one of them 300 times; all those tested work as well as when first used. To put a cap on and off takes less than a second.

The Use of the Models for illustrating General Organic Chemistry.

It is true that in using the models for this purpose our instructions are liable to become permeated with ideas as to the relative positions of atoms, ideas which we have not hitherto allowed to exert much influence on such teaching. But it is also doubtless true that an analogous statement could at one time have been made with regard to the introduction of structural formulæ. These, however, have long since emerged from the study of the investigator who, to make plain to himself his own conceptions, first used them, and now cover our blackboards. Similarly stereochemical models which already find a place on the study-

[1] The upright rods on which the models are supported have been omitted from the plates.

tables of the few, must sooner or later cover our lecture-tables. Solid formulæ will partially supersede structural formulæ, as these have partially superseded empirical formulæ, and the gain in our power of concise and rapid thinking, similar in origin, will possibly be comparable in degree. As structural formulæ are more cumbersome to use than empirical, so are solid more cumbersome than structural formulæ; but in each case the more ample formula best stenographs our thought. And when a solid formula is once arranged it takes no more time to alter it, by exchanging one cap for another, than to turn to the blackboard and make the alteration in a written formula; in manipulating the models we have, too, the advantage of always facing the audience.

As to the dangers which are incident to the use of all formulæ, the history of stereochemistry shows that we must especially guard against proceeding faster than our knowledge warrants in the allotment of formulæ; on the other hand, the danger of cramping rather than stimulating thought is perhaps less formidable in the case of solid than of other formulæ.

It is well, however, in discussing the advantage of using solid formulæ, to consider particular cases. For instance, the fact that it is matter of indifference which hydrogen-atom in methane be exchanged for a given radical has been illustrated by means of the models of Kekulé;[1] the solid formulæ are equally effective, and with them we may illustrate the replacement of hydrogen by any given radical, and this without straining the memory to connect H, Br, CH_3, etc., with the particular color assigned to it. Next, the cap marked CH_3, which has represented methyl acting as an element, may be replaced by a block with three caps marked H; with the aid of this double means of representation the conception of a compound radical is readily imparted; similarly we may develop $-C_2H_5$ to $-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}H$, or to $-\overset{H}{\underset{H}{C}}-CH_3$. The derivation of the series CH_4, C_2H_6, etc., and of the general formula C_nH_{2n+2} is clearly seen; the tendency to ring-formation and the stability of rings of five or six carbon-atoms are explained at once.[2] Further, we may show the double- and the triple-linking of carbon-atoms; the diminution in the number of atoms bound by carbon-atoms so linked is represented by the impossi-

[1] See, however, Le Bel: Bull. Soc. Chim. [3] **3**, 788.

[2] See Plate in the report on Stereochemistry.

bility of covering by caps those of the tetrahedron corners which are in contact, and the formulæ C_nH_{2n} and C_nH_{2n-2} are deduced. Some of the facts mentioned might be represented by plane structural formulæ; but the representation of all the facts in the same way strengthens their connection in the mind.

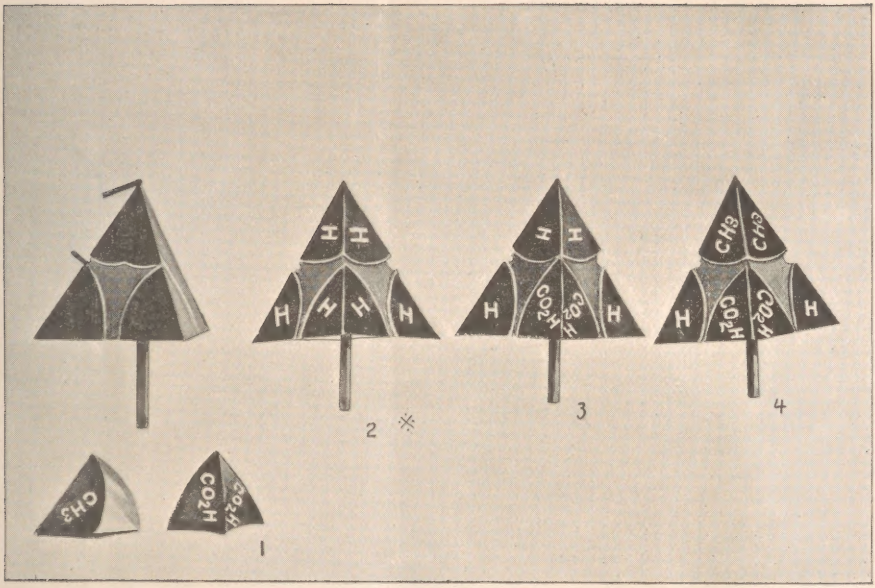
The Special Use of the Models in Stereochemistry.

For a general explanation of the isomerism of compounds of the type $CR^1R^2R^3R^4$, the models of Kekulé or those of Van't Hoff may be used; it is when we have to deal with particular compounds (such, for instance, as the lactic acids) that we find the use of the models with letter-symbols desirable if not indispensable.

We may also not only show the general relations of radicals attached to two carbons singly-linked, the effect of the relative rotation of these carbons and of the inclination of the axes round which the two sets of radicals are ranged, but we may give solid formulæ to any compound of the type $C_2R^1R^2R^3R^4R^5R^6$; we may show, side by side, the three solid formulæ for tartaric acid, how two of these together represent racemic acid, and how this acid is necessarily the product of the addition of four hydroxyl groups to two molecules of fumaric acid, while it is mesotartaric acid that must result from similar treatment of maleïc acid. The solid formulæ of fumaric and maleïc acid render Van't Hoff's theory as to their isomerism at once clear, and all the transformations attributable to their different configuration are traced with ease by means of the models. There are, in fact, but few configurations known to the stereochemistry of carbon which cannot be thus represented.

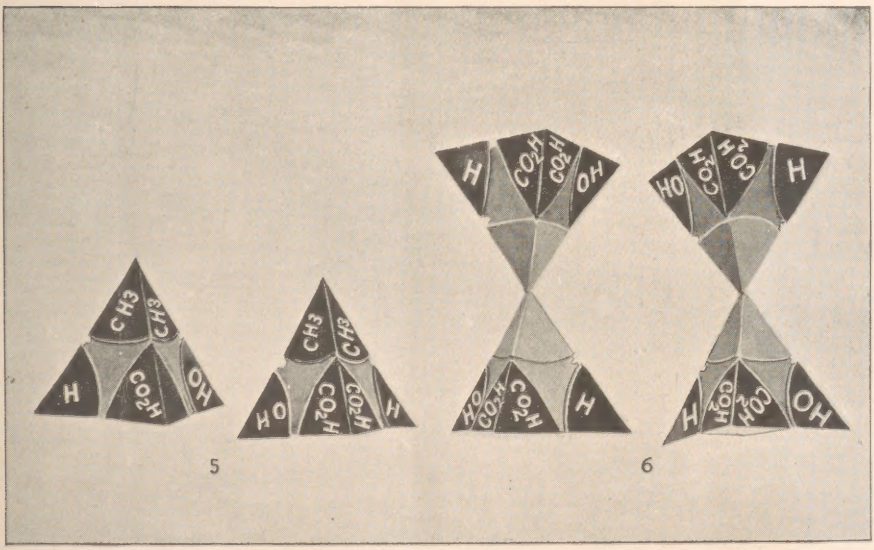
An objection to the particular form of model here described is yet to be noticed. The configurations of Wunderlich perhaps more nearly represent the truth than do those of Van't Hoff, and the former, it may be urged, should be taken into account in any attempt to extend the use of stereochemical models. Unfortunately, Wunderlich's configurations would require the use of transparent models in order that the formulæ of the radicals attached to the carbon-atoms might all be visible at once. Besides, the models described may be used to illustrate the general nature of the theories of Wunderlich, and they represent after all the four points equidistant in space about which Wun-

PLATE I.

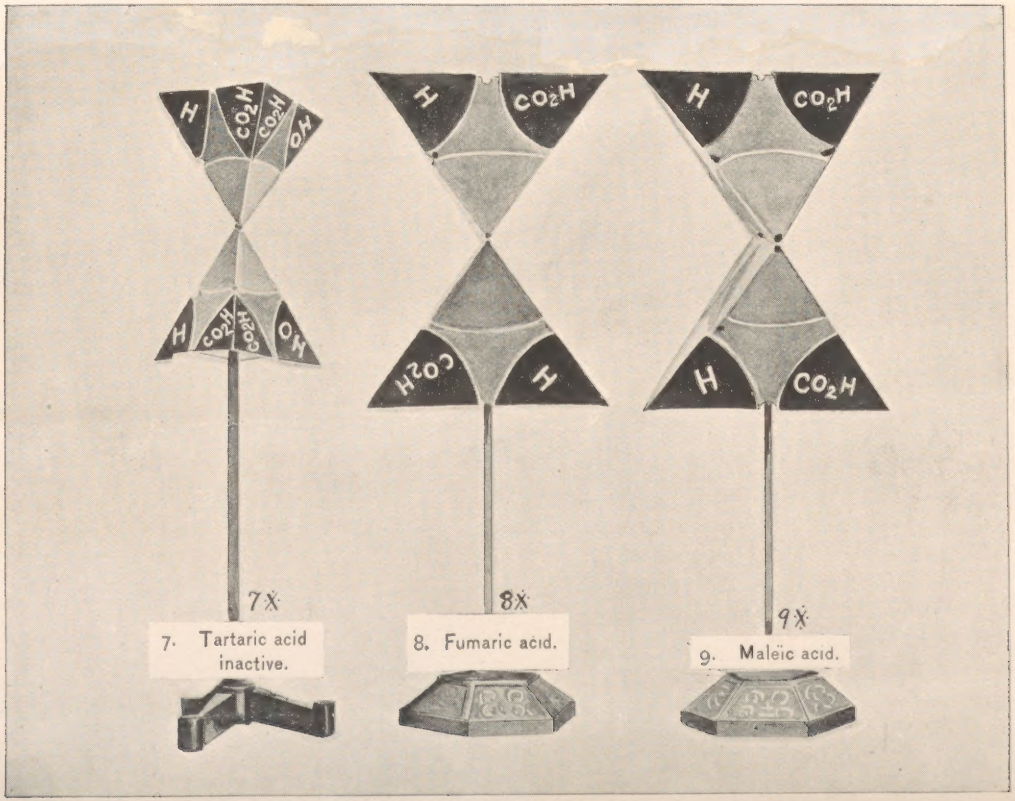


1. Separate parts of model. 2. Methane. 3. Acetic acid. 4. Propionic acid.

PLATE II.



5. Lactic acids (right and left-handed). 6. Tartaric acids (right and left-handed).



7. Tartaric acid inactive.

8. Fumaric acid.

9. Maleïc acid.

derlich's figures for the form of the carbon-atom are described. To illustrate further the theories of Wunderlich and Skraup[1] two large round-bottomed flasks may be used. The necks serve as handles, and four equidistant points on the outside of each flask are marked with colors or letters.

Details of Construction.

The dimensions given need not be followed exactly; but for every model the dimensions should be the same, so that the parts may be interchangeable.

The *tetrahedra*, 13 cm. (5 in.) in the edge, are cut from a long triangular prism of white wood 13 cm. in the side. At each corner is bored a hole of 0.5 cm. ($\frac{3}{16}$ in.) in diameter and 4 cm. ($1\frac{5}{8}$ in.) deep. Lining this and firmly fitted into it is a brass tube of 0.4 cm. ($\frac{3}{32}$ in.) internal diameter, projecting only about 0.1 cm. Slight variation in the length projecting, in order to correct inequality in the length of the edges, is permissible. In the middle of each edge is bored a hole 0.5 cm. wide at the mouth and tapering to 0.3 cm. ($\frac{1}{8}$ in.) at 0.3 cm. from the mouth; the hole then continues 3 cm. ($1\frac{1}{4}$ in.) deeper, the diameter of this part being adjusted to that of the rod which is to support the block. (A bill-file with loaded foot may be used.) In the middle of one face is bored a similar hole to fit the rod; no enlargement at mouth. If many connected blocks are to be supported it is well to make in the middle of one face a hole large enough to receive the rod of a retort-stand having three feet.

The position of the grooves on the tetrahedron-faces is marked by drawing a line along the free edges of a cap pushed home on one of the tetrahedron-corners. The groove, which at its widest part is about 0.3 cm. across, slopes downwards towards the curve so described, where its depth is greatest—not more than 0.08 cm. ($\frac{1}{32}$ in.) Six blocks suffice for most purposes, but for benzene-derivatives more will be necessary.

The *caps* are made of tin-plate about 0.5 mm. ($\frac{1}{50}$ in.) thick, and measure about 6.3 cm. ($2\frac{1}{2}$ in.) in the edge; fitted on to a block, a cap then comes within about 0.5 cm. ($\frac{1}{4}$ in.) of the centre of the block-edge. The cap is painted black, and on each of its three sides the symbol of the element or group for which it stands is

[1] Monatsh. Chem. **12**, 146.

stencilled in white or gold.[1] It is well to have about forty caps, six marked H, four Cl, four Br, four I, four OH, two CH_3, two C_2H_5, two C_6H_5, four COOH, and some caps unlettered for marking with chalk at will.

The *hinged rods* have each limb 3.5 cm. ($1\frac{7}{16}$ in.) long, and are 0.3 cm. ($\frac{1}{8}$ in.) thick, so that they slide freely in the brass tubes of the corner holes.

The *pins* are 2.5 cm. (1 in.) long, 0.5 cm. ($\frac{3}{16}$ in.) thick in the middle, and taper down to 0.3 cm. at the ends. A pin pushed into one of the holes in the edge-centres must sink in a little more than half way; the part left outside the hole will then not fit a similar hole too tightly, so that another block may be put on and removed without disturbing the pin; that this may be done without allowing too much side-play to the blocks joined by the pin, care in adjusting the dimensions of the pins and holes is necessary.

The dimensions given are those of the models used by me; for a very large lecture-room larger blocks and caps would be necessary in order that the letters might be written larger; but blocks 15 cm. (6 in.) and caps 7.5 cm. in the edge would answer every purpose.

The work connected with this paper was done at Cornell University. I take this opportunity of expressing my thanks to Mr. Lester J. Young, instructor in Architecture, without whose valuable aid in word and deed it would have been hardly possible to bring the models to their present state.

NEW YORK, *October*, 1891.

[1] To protect the letters two small knobs of solder are placed on each face, one near each end of its free edge. The caps may then be packed one inside another without injury. This addition had not been made when the photographs were taken.